Name: SID:
Discussion Section: (Deborah, Heidi, Josh)

Exam #2
Biophysical Chemistry
Chemistry 130A
Fall 2001

Justify all your assumptions!

Show <u>all</u> your calculations!

Make sure all your conclusions are physically reasonable.

Keep track of units and significant digits!

Underline or Box all your final answers!

Exams in pencil won't be regraded.

Keep your answers short!

Problem	*TA*	*Score*
1		
2		
3		
4		
Total		

R= 8.3145 J/(K mol) = 0.08206 L atm / (K mol)

F=Faraday's constant= 9.6485 x 10^4 C/mol

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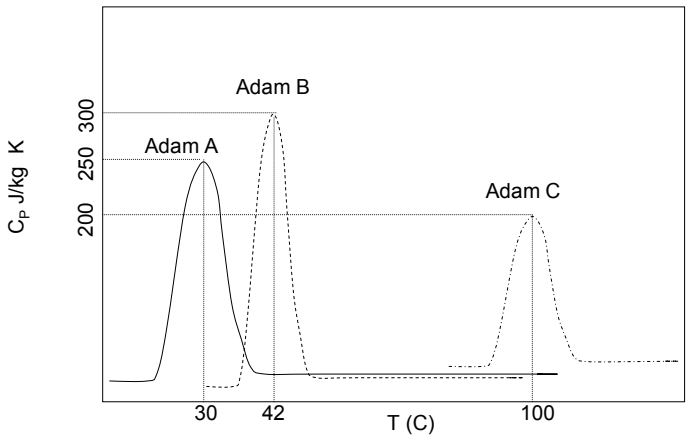
1.Short answers and multiple choice (10 pts)

(a) On a voyage to the fantastic planet Funkatronica, you encounter three people who all look and act exactly like Adam Arkin. All three claim to be him and want you take them back to Earth. To find the real Adam Arkin, you obtain a cellular sample from each Adam and extract/purify DNA ligase. You analyze the enzyme from each of the three Adams in a calorimeter. This is the data you obtain:



Which Adam is the real Adam? Explain BRIEFLY why. (Remember, we think the REAL Adam is human.)

(b) Multiple Choice

(i) What is the γ_A, the activity coefficient of the solute, for an ideal solution?

(a) 0.98
(b) 1
(c) 1.02
(d) It depends on the temperature and the identity of the solute.

(ii) The reaction A → 2 B is known to occur. Upon measuring a solution which has just been prepared in the laboratory with 1 mole of A and 2 moles of B, it is found that μ_A= 3.4 J/mol and μ_B= 1.7 J/mol. What is true about the solution.

(a) More reactants will form.
(b) More products will form.
(c) The reaction is in equilibrium, so there will be no change in amount of products or reactants.
(d) There is not enough information to tell.

2. (18 pts) A main source of acidity and flavor in coffee are non-volatile monocarboxylic acids such as 3-monocaffeoquinic acid (Cq-H). Assume that these can be approximated as being a single acid, Cq-H, with $pK_a = 3.40$ at 60 °C (chemist's standard state). Imagine starting with fully undissociated acid at 400 μmol/100 mL in Coffee. It undergoes the following dissociation reaction:

$$Cq\text{-}H + H_2O \Leftrightarrow Cq^- + H_3O^+$$

(a) Given that the pH of coffee is 5.41, calculate $[Cq^-]$, [Cq-H], and $[H_3O^+]$ present at equilibrium in a 60 °C cup of coffee.

(b) What temperature would you have to go to in order to make your coffee pH 7.0? Assume $\Delta H°$ for the dissociation reaction above is 440 kJ/mol (typical for mono-carboxylic acids). Use the chemist's standard state.

(c) You add 60.0 g (~ 2 oz.) of milk at 7 °C to your mug of 280 g (~ 10 oz) coffee at 60 °C. Assuming that the heat capacity of coffee and milk are both equal to that of water (4.184 J/g K), what is the change in entropy due to the temperature change that results? (Neglect any heat loss to the environment; assume a closed system).

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3. (16 pts) A Problem in which the *Humble Chicken* is confronted by the *Monstrous Virus*. Who will prevail?

Animal virus 5 (AV5) infects a wide range of species with near 100 % fatality when even as few as 10 active viruses are in the animal. A scientist who is studying it has determined that the following reaction takes place:

$$AV5^{3+} + 3/2\ H_2 \Leftrightarrow 3\ H^+ + AV5$$

The ε° for this reaction in the chemist's standard state is 0.111V. One major finding is that it is only the oxidized form of the virus that is virulent—the reduced form is harmless.

(a) Write the half reaction for the reduction of AV5, and determine its ε°' at the biochemist's standard state (T=298K).

(b) Cha-Cha is a vampire chicken. The vampire part means that there are several physiological differences between Cha-Cha and a normal chicken. Cha-Cha is at pH= 7.0 (which is normal): However, Cha-Cha's temperature is 25 C, and Cha-Cha's blood has 1 atm of H_2 in it. If Cha-Cha is infected with 10,000 copies of the AV5 virus, how many will remain in the virulent form? How do you rate Cha-Cha's chance for survival?

4. (16 pts) Collagen is a protein that forms molecular cables in our body. These cables strengthen tendons and help support our internal organs. Collagen makes up approximately one fourth of all the proteins in our body. Since its volume is relatively insensitive to pressure changes, processes that stress these cables are poorly characterized by standard pressure/volume work. We can, however, say that the work done on collagen is of the force distance type. Therefore, we will develop a system analogous to the thermodynamics we discussed previously in order to apply it to this important molecule.

For a system with only force-distance work:

$$dE = T\,dS + f\,dL$$

The analogous definitions for enthalpy and Gibbs free energy are

$$H = E - fL$$
$$G = H - TS$$

(a) Write dH and dG as functions of T,S,f and L only.

(b) Demonstrate that $\left(\frac{\partial G}{\partial T}\right)_f = -S$ and $\left(\frac{\partial G}{\partial f}\right)_T$ = -L.

(c) Now show that $\left(\frac{\partial S}{\partial f}\right)_T = \left(\frac{\partial L}{\partial T}\right)_f$.

(d) A scientist studying the strand of collagen has determined that its length depends on the forces and the temperature as follows:

$$L= a*f*T + C$$

Where L is the length, f is the applied force, T is the temperature, and 'a' and 'C' are constants with $a = 1\frac{m}{NK}$ and C= 3μm. Using 4c, determine ΔS when the force on the collagen changes from 1 N to 2N at 310K. Remember 1 J = 1 N m.